

Land surface Verification Toolkit (LVT)

User's Guide

December 4, 2012

Revision 1.0

History:

Revision	Summary of Changes	Date
1.0	Initial version for LIS 6.0	August, 2009



**National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771**

Contents

1	Introduction	4
1.1	What's New	4
1.1.1	Version 1.0	4
2	Background	5
2.1	LVT	5
2.2	Summary of key features	5
3	Preliminaries	7
4	Obtaining the Source Code	8
4.1	Downloading the Source Code	8
5	Building the Executable	9
5.0.1	Development Tools	9
5.0.2	Required Software Libraries	9
5.0.3	Optional Software Libraries	9
5.0.4	Build Instructions	10
5.1	Generating documentation	12
6	Running the Executable	13
7	LVT config File	14
7.1	Overall driver options	14
7.2	Runtime options	17
7.3	Domain specification	20
7.3.1	Cylindrical lat/lon	20
7.3.2	Cylindrical lat/lon	20
7.4	Analysis options specification	24
7.5	Observation sources	29
7.5.1	LIS LSM output as the observation	30
7.5.2	CEOP station observations	30
7.5.3	ISCCP land surface temperature observations	31
7.5.4	SCAN soil moisture observations	31
7.5.5	COOP snow depth observations	32
7.5.6	SURFRAD radiation observations	33
7.5.7	Walnut Gulch PBMR soil moisture observations	34
7.5.8	SNOTEL SWE observations	34
7.5.9	GSOD snow depth observations	34
7.5.10	LSWG Tb observations	35
7.5.11	FMI SWE observations	36
7.5.12	CMC's daily snow depth observations	36
7.5.13	SNODAS snow analysis data	36
7.5.14	NASA AMSR-E soil moisture retrievals	37
7.5.15	NESDIS AMSR-E soil moisture retrievals	37

7.5.16	VU AMSR-E soil moisture retrievals	37
7.5.17	AMMA station observations	37
7.5.18	Ameriflux station observations	38
7.5.19	ARM station observations	39
7.5.20	SMOSREX in-situ soil moisture observations	40
7.5.21	AGRMET data	40
7.5.22	GlobSnow data	40
7.5.23	SNODEP data	40
7.6	DA diagnostics analysis	40
7.7	Observation processing	41
7.8	DA observation analysis	41
7.9	Optimization/Uncertainty Estimation output analysis	41
8	Configuration of metrics	43
9	Model Output Specifications	46
A	How to verify a “non-LIS” dataset?	50
B	Description of output files from LVT	51
B.0.1	METADATA files	51
B.0.2	Stats summary file	52
B.0.3	ASCII Time Series files	53
B.0.4	Domain time Series files (Binary/NETCDF)	54
B.0.5	Final domain files (Binary/NETCDF)	54
C	Cylindrical Lat/Lon Domain Example	55
D	Polar Stereographic Domain Example	60
E	Gaussian Domain Example	61
F	Lambert Conformal Domain Example	65
G	Mercator Domain Example	66
H	UTM Domain Example	67

1 Introduction

This is the User's Guide for Land surface Verification Toolkit (LVT;[1]). This document describes how to download and install LVT codes and instructions on building an executable.

This document consists of several sections, described as follows:

- 1 Introduction:** the section you are currently reading
- 2 Background:** general information about the LVT
- 3 Preliminaries:** general information, steps, instructions, and definitions used throughout the rest of this document
- 4 Obtaining the Source Code:** the steps needed to download the source code
- 5 Building the Executable:** the steps needed to build the LVT executable

1.1 What's New

1.1.1 Version 1.0

1. This is the initial version developed for evaluating output from LIS version 6.0 or higher.

2 Background

Verification and evaluation are essential processes in the development and application of simulation models. The Land surface Verification Toolkit (LVT) is an integrated framework designed specifically for evaluating land surface model (LSM) outputs. The system was originally designed as a post processor to the NASA Land Information System (LIS), which is an integrated framework to conduct multi-model land surface model simulations and data assimilation integrations. LVT also includes the capabilities to convert any land surface-specific dataset to a “LIS output format/style”, thus enabling cross-comparisons of a broad set of land surface datasets (in-situ, remotely sensed, and reanalysis products).

2.1 LVT

LVT provides a formal system for LSM output evaluation and verification. The capabilities of LVT also provides a tool to systematically evaluate and benchmark LSM performance and the impact of computational enhancements such as data assimilation. LVT includes a range of both deterministic and probabilistic verification measures, with similarity-based and object-based methods in development.

LVT is designed as an object oriented framework, with a number of points of flexibility known as “plugins”. Specific implementations are added to the framework through the plugin-interfaces. LVT uses the plugin-based architecture to support the processing of different types of observational data sets, ranging from in-situ, satellite and remotely sensed and reanalysis products.

In addition to providing methods for model output verification, LVT also provides capabilities to analyze the outputs from LIS data assimilation (LIS-DA) and the LIS optimization and uncertainty estimation (LIS-OPTUE) subsystems.

2.2 Summary of key features

The key capabilities of LVT can be summarized as follows:

- Capability to convert a given dataset to “LIS-style format”
- A text-based, configurable input interface
- Supports a broad range of in-situ, remotely-sensed and reanalysis data products. For e.g.:
 - Surface fluxes - Ameriflux, ARM, CEOP, AMMA
 - Soil moisture - SCAN, SMOSREX, AMSR-E retrievals
 - Snow - COOP, GSOD, SNODAS, SNOADEP, CMC, FMI, GlobSnow, SNOTEL
 - LST - ISCCP

– Radiation - SURFRAD

- A number of deterministic and probabilistic verification measures. E.g. RMSE, Bias, Correlations, POD, FAR, etc.
- Supports the computation of land surface model diagnostics and closure checks. E.g.: Energy, water balance checks, seasonal and average diurnal cycles
- Options of time series extraction of individual grid points and area averages
- Options of temporal averaging. E.g. : Comparisons at hourly, daily, monthly scales
- Options for data masking. E.g. Apply an external mask to the comparisons, apply thresholds on the comparisons
- Supports the analysis of outputs from LIS-OPTUE and LIS-DA subsystems. For e.g: Analysis of normalized innovations from LIS-DA

3 Preliminaries

This section provides some preliminary information to make reading this guide easier.

Commands are written like this:

```
% cd /path/to/LVT  
% ls  
“... compiler flags, the run gmake.”
```

File names are written like this:

/path/to/LVT/src

You need to create a working directory on your system to install LVT. Let's call this directory */path/to/LVT/*. Throughout the rest of this document, this directory shall be referred to as *\$WORKING*. You should create a directory to run LVT in. This directory can be created anywhere on your system, but, in this document, we shall refer to this running directory as *\$WORKING/run*.

4 Obtaining the Source Code

This section describes how to obtain the source code needed to build the LVT executable.

4.1 Downloading the Source Code

To obtain the source code needed for LVT, you can follow the download links from the LVT web page <http://lis.gsfc.nasa.gov/LVT/>.

Go to the working directory and uncompress the source code.

5 Building the Executable

This section describes how to build the source code and create LVT executable

5.0.1 Development Tools

This code has been compiled and run on Linux PC (Intel/AMD based) systems, IBM AIX systems, and SGI Altix systems. These instructions expect that you are using such a system. In particular you need

- Linux
 - Intel fortran compiler, version 11 or higher
 - or
 - Lahey/Fujitsu’s Fortran 95 Compiler, release L6.00c
 - GNU’s C and C++ compilers, gcc and g++, version 3.3.3
 - GNU’s make, gmake, version 3.77
- IBM
 - XL Fortran version 10.1.0.6
 - GNU’s make, gmake, version 3.77
- SGI Altix
 - Intel Fortran Compiler version 11 or higher
 - GNU’s make, gmake, version 3.77

5.0.2 Required Software Libraries

In order to build the LVT executable, the following libraries must be installed on your system:

- Earth System Modeling Framework (ESMF) version 5.2.0rp1 or higher (<http://earthsystemmodeling.org/>)

Please read the ESMF User’s Guide for details on compiling ESMF with MPI support and without MPI support (“mpiuni”). Note that ESMF must be compiled with MPI support for using LIS-WRF system in a multiprocessor environment.

5.0.3 Optional Software Libraries

The following libraries are not required to compile LVT. They are used to extend the functionality of LVT.

- GRIB-API

GRIB-API is developed by ECMWF and supports both grib1 and grib2 formats.

Download the source from (<https://software.ecmwf.int/wiki/display/GRIB/Home>) and compile the source to generate the GRIB-API library.

- NETCDF

If you choose to have NETCDF support, please download the netcdf source (<http://www.unidata.ucar.edu/software/netcdf/>) and compile the source to generate the NETCDF library.

- HDF4

HDF4 version is used to support a number of remote sensing datasets.

Please download the version 4.2r4 from (<http://www.hdfgroup.org/products/hdf4/>).

- HDF5

Download the version hdf5-1.8.8 from (<http://www.hdfgroup.org/HDF5/>).

- HDFEOS

Please download the hdfeos source from (<http://hdfeos.org>) HDF5 version is used to support a number of remote sensing datasets.

To install these libraries, follow the instructions provided at the various URL listed above. Please note that though GRIB-API and NETCDF are optional, they are highly recommended as the functionality of LVT will be hugely reduced without these two libraries.

5.0.4 Build Instructions

1. Perform the steps described in Section 4 to obtain the source code.
2. Goto the `$WORKING/src/` directory. This directory contains two scripts for building the LVT executable: `configure` and `compile`.

3. Run the `configure` script first by typing:

```
% ./configure
```

This script will prompt the user with a series of questions on the locations of the required and optional libraries, requiring that a series of environment variables be set. The following environment variables are required by LVT.

Variable	Description
LVT_SRC	Location of the LVT source tree (<i>\$WORKING/src/</i>)
LVT_ARCH	LVT architecture (See below)
LVT_FC	Fortran compiler to be used (<i>mpif90</i> , if mpi is installed)
LVT_CC	C compiler to be used (<i>mpicc</i> , if mpi is installed)
LVT_GRIBAPI	path to grib api library
LVT_NETCDF	path to NETCDF library
LVT_HDF4	path to HDF4 library
LVT_HDF5	path to HDF5 library
LVT_HDFEOS	path to HDFEOS library
LVT_MODESMF	path to ESMF header files
LVT_LIBESMF	path to ESMF library files

It is suggested that these definitions are made in your *.profile* (or equivalent) startup file.

4. The LVT_ARCH environment variable based on the system you are using. The following commands are written using Bash shell syntax.

- For an AIX system
`% export LVT_ARCH=AIX`
- For a Linux system with the Intel Fortran compiler
`% export LVT_ARCH=linux_ifc`
- For a Linux system with the Intel Fortran and gcc C compiler
`% export LVT_ARCH=linux_gcc`
- For a Linux system with the Absoft Fortran compiler
`% export LVT_ARCH=linux_absoft`
- For a Linux system with the Lahey Fortran compiler
`% export LVT_ARCH=linux_lf95`

It is suggested that you place this command in your *.profile* (or equivalent) startup file.

5. An example execution of the configure script is shown below:

```
% ./configure
-----
Setting up configuration for LVT version 1.0...
Parallelism (0-serial, 1-dmpar): 0
Optimization level (-2=strict checks, -1=g, 0,1,2,3): 2
Use NETCDF? (1=yes, 0-no): 1
NETCDF version (3 or 4)?: 4
Use HDF4? (1=yes, 0-no): 1
Use HDF5? (1=yes, 0-no): 1
Use HDFEOS? (1=yes, 0-no): 1
-----
```

```
configure.lvt file generated successfully
-----
Settings are written to configure.lvt in the make directory
If you wish to change settings, please edit that file.
To compile, run the compile script.
-----
```

6. Compile the LVT source code by running the *compile* script. % *./compile*
This script will compile the libraries provided with LVT, the dependency generator and then the LVT source code. The executable *LVT* will be placed in the *\$WORKING/src/* directory upon successful completion of the *compile* script.
7. Finally, copy the *LVT* executable into your running directory, *\$WORKING/run*.

5.1 Generating documentation

LVT code uses the ProTex documenting system [2]. The documentation in \LaTeX format can be produced by using the *doc.csh* in the *\$WORKING/src/utils* directory. This command produces documentation, generating a number of \LaTeX files. These files can be easily converted to pdf or html formats using utilites such as *pdflatex* or *latex2html*.

6 Running the Executable

This section describes how to run the LVT executable.

The single-process version of LVT is executed by the following command issued in the `$WORKING/run/` directory.

```
% ./LVT <configfile>
```

where `<configfile>` represents the file containing the run time configuration options for LVT. Currently LVT only supports a serial mode.

To customize your run, you must specify a LVT runtime configuration file. See Section 7 for more information.

7 LVT config File

This section describes the options in the *lvt.config* file.

7.1 Overall driver options

LVT running mode: specifies the running mode to be used Acceptable values are:

Value	Description
"Observation processing"	observation processing (to convert to a "LIS format")
"LIS output processing"	standard analysis mode where analysis is conducted on the LIS output
"DA statistics processing"	data assimilation diagnostics analysis
"DA observation processing"	data assimilation observation analysis
"OPTUE output processing"	parameter estimation/uncertainty output analysis
"RTM output processing"	radiative transfer model output analysis

LVT running mode:	"LIS output processing"
-------------------	-------------------------

Map projection of the LIS run: specifies the map projection used in the LIS simulation Acceptable values are:

Value	Description
latlon	Lat/Lon projection with SW to NE data ordering
mercator	Mercator projection with SW to NE data ordering
lambert	Lambert conformal projection with SW to NE data ordering
gaussian	Gaussian domain
polar	Polar stereographic projection with SW to NE data ordering
UTM	UTM domain

Map projection of the LIS run: "latlon"

LIS nest index: specifies the nest index of the LIS output being compared using LVT

LIS nest index:	1
-----------------	---

Number of surface model types: specifies the number of surface model types used in the LIS simulation

Number of surface model types:	1
--------------------------------	---

Surface model types: specifies the surface model types used in the LIS simulation, in consecutive columns. Acceptable values are:

Value	Description
LSM	land surface model types
Lake	Lake model types

Surface model types: "LSM"

LIS output source: specifies the specific subsystem within LIS that generated the output being analyzed Acceptable values are:

Value	Description
LSM	LSM output
ROUTING	Routing output
RTM	RTM output

LIS output source: "LSM"

LIS output format: specifies the format of the LIS output data. Acceptable values are:

Value	Description
binary	LIS output in binary format
grib1	LIS output in Grib format
netcdf	LIS output in NETCDF format

LIS output format: "netcdf"

LIS output naming style: specifies the style of the model output names and their directory organization Acceptable values are:

Value	Description
"5 level hierarchy"	5 levels of hierarchy
"3 level hierarchy"	3 levels of hierarchy
"2 level hierarchy"	2 levels of hierarchy
"WMO convention"	WMO convention for weather codes

LIS output naming style: "5 level hierarchy"
--

LIS output methodology: specifies the output methodology used in the LIS simulation. The LIS output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

Value	Description
"1d tilespace"	LIS output in a 1-D tile domain
"2d gridspace"	LIS output in a 2-D grid domain
"1d gridspace"	LIS output in a 1-D grid domain

LIS output methodology:	"2d gridspace"
-------------------------	----------------

LVT output format: specifies the format of the LVT output. Acceptable values are:

Value	Description
binary	Write output in binary format
grib1	Write output in Grib format (not supported yet)
netcdf	Write output in NETCDF format

See Appendix B for more details about the structure of the LVT output files.

LVT output format:	netcdf
--------------------	--------

LVT output methodology: specifies the output methodology used in LVT. The LVT output is written as a 1-D array containing only land points or as a 2-D array containing both land and water points. 1-d tile space includes the subgrid tiles and ensembles. 1-d grid space includes a vectorized, land-only grid-averaged set of values. Acceptable values are:

Value	Description
"1d tilespace"	LVT output in a 1-D tile domain
"2d gridspace"	LVT output in a 2-D grid domain
"1d gridspace"	LVT output in a 1-D grid domain

LVT output methodology:	"2d gridspace"
-------------------------	----------------

Map projection of parameter data: specifies the map projection of the parameter datasets. Note that the grid description options for the parameters will be different for different map projections

Acceptable values are:

Value	Description
latlon	Equidistant cylindrical (lat/lon)
mercator	Mercator projection
lambert	Lambert conformal projection
gaussian	Gaussian
polar	Polar Stereographic
UTM	UTM projection

Map projection of parameter data: "latlon"
--

Observation source: specifies the observational data to be used for comparing LIS model output

Acceptable values are:

Value	Description
”none”	template
”LIS LSM”	output from another LIS run
”CEOP”	CEOP station observations
”ISCCP tskin”	ISCCCP skin temperature observations
”SCAN”	SCAN soil moisture station observations
”ISMN”	ISMN soil moisture station observations
”COOP”	COOP snow depth observations
”SURFRAD”	SURFRAD radiation observations
”WG PBMRsm”	PBMR soil moisture observations at Walnut Gulch
”SNOTEL”	SNOTEL snow water equivalent observations
”GSOD”	GSOD snow depth observations
”LSWG Tb”	Tb brightness temperature observations at the LSWG sites
”FMI SWE”	Finnish Meteorological Institute (FMI) snow course data
”CMC”	Canadian Meteorological Center’s (CMC) snow depth analysis
”SNODAS”	NOHRSC’s SNOW Data Assimilation (SNODAS) product
”AMSR-E NASA”	NASA (NSIDC) retrieval of AMSR-E soil moisture
”AMSR-E NESDIS”	NESDIS retrieval of AMSR-E soil moisture
”AMSR-E LPRM”	LPRM (VU) retrieval of AMSR-E soil moisture
”AMMA”	AMMA station observations
”Ameriflux”	Ameriflux station observations
”ARM”	ARM station observations
”SMOSREX”	SMOSREX station observations
”AGRMET”	AGRMET land surface analysis
”Globssnow”	GlobSnow SWE analysis
”SNODEP”	WMO snow depth station observations
”MOD10A1”	MOD10A1 fractional snow cover data from MODIS
”ANSA snowdepth”	ANSA snow depth retrievals
”ANSA SWE”	ANSA SWE retrievals
”CPC precipitation”	CPC unified precipitation product
”USGS streamflow”	USGS streamflow observations
”FLUXNET”	Gridded FLUXNET data from MPI
”MOD16A2”	MOD16A2 ET products from MODIS
”USDA ARS soil moisture”	soil moisture measurements from USDA ARS watersheds
”GHCN”	Global Historical Climatology Network data

Observation source:	”SURFRAD”
---------------------	-----------

7.2 Runtime options

Start mode: specifies if the LVT analysis is to be restarted from a previous (unfinished) analysis. Note that if ”restart” option is selected, then the starting time (below) must be changed appropriately.

Acceptable values are:

Value	Description
coldstart	Fresh analysis
restart	Restart from a previous analysis

```
Start mode: "coldstart"
```

LVT restart output interval: specifies the frequency at which the restart files must be written during a LVT analysis. The time interval is specified with a number followed by a 2 character suffix that indicates the units. For example, a restart interval of 1 hour can be specified as "1hr", "60mn", or "3600ss".

Acceptable values for the 2 character suffix are : Acceptable values are:

Value	Description
ss	second
mn	minute
hr	hour
da	day
mo	month
yr	year

```
LVT restart output interval: "1mo"
```

LVT restart filename: specifies the name of the LVT restart file

```
LVT restart filename: "none"
```

The start time of the evaluation period is specified in the following format:

Variable	Value	Description
Starting year:	integer 2001 – present	specifying starting year
Starting month:	integer 1 – 12	specifying starting month
Starting day:	integer 1 – 31	specifying starting day
Starting hour:	integer 0 – 23	specifying starting hour
Starting minute:	integer 0 – 59	specifying starting minute
Starting second:	integer 0 – 59	specifying starting second

```
Starting year: 2007
Starting month: 11
Starting day: 1
Starting hour: 0
Starting minute: 0
Starting second: 0
```

The end time of the evaluation period is specified in the following format:

Variable	Value	Description
Ending year:	integer 2001 – present	specifying ending year
Ending month:	integer 1 – 12	specifying ending month
Ending day:	integer 1 – 31	specifying ending day
Ending hour:	integer 0 – 23	specifying ending hour
Ending minute:	integer 0 – 59	specifying ending minute
Ending second:	integer 0 – 59	specifying ending second

Ending year:	2008
Ending month:	5
Ending day:	31
Ending hour:	0
Ending minute:	0
Ending second:	0

LIS output temporal convention: specifies the temporal style of LIS outputs
Acceptable values are:

Value	Description
regular	outputs at regular time intervals
dekad	outputs at irregular, dekad intervals

LIS output temporal convention:	"regular"
---------------------------------	-----------

LIS output timestep: specifies the frequency of model outputs used in the LIS simulation

LIS output timestep:	"1da"
----------------------	-------

Undefined value: specifies the undefined value. The default is set to -9999.

Undefined value:	-9999
------------------	-------

LVT diagnostic file: specifies the name of run time diagnostic file. Acceptable values are any 40 character string.

LVT diagnostic file:	lvtlog
----------------------	--------

LIS output directory: specifies the name of the top-level LIS output directory. Acceptable values are any 40 character string. For simplicity, throughout the rest of this document, this top-level output directory shall be referred to by its default name, \$WORKING/LIS/OUTPUT.

LIS output directory:	./CTRL/OUTPUT
-----------------------	---------------

Number of ensembles per tile: specifies the number of ensembles of tiles used in the LIS simulation. The value should be greater than or equal to 1.

Number of ensembles per tile:	1
-------------------------------	---

This section specifies the 2-d layout of the processors in a parallel processing environment. The user can specify the number of processors along the east-west dimension and north-south dimension using **Number of processors along x:** and **Number of processors along y:**, respectively. Note that the layout of processors should match the total number of processors used. For example, if 8 processors are used, the layout can be specified as 1x8, 2x4, 4x2, or 8x1.

NOTE:Currently parallel processing is not supported within LVT. So these options are ignored.

Number of processors along x:	2
Number of processors along y:	2

7.3 Domain specification

LVT expects three sets of domain specification. (1) the domain over which the LVT analysis needs to be carried out (2) the domain in which LIS simulation was carried out (LIS run domain) Section 7.1 lists the projections that LIS supports.

7.3.1 Cylindrical lat/lon

This section describes how to specify a cylindrical latitude/longitude projection. See Appendix C for more details about setting these values.

Run domain lower left lat:	30.125
Run domain lower left lon:	-124.875
Run domain upper right lat:	50.125
Run domain upper right lon:	-69.875
Run domain resolution (dx):	0.25
Run domain resolution (dy):	0.25

7.3.2 Cylindrical lat/lon

This section describes how to specify a cylindrical latitude/longitude projection. See Appendix C for more details about setting these values.

LIS run domain lower left lat:	30.125
LIS run domain lower left lon:	-124.875
LIS run domain upper right lat:	50.125
LIS run domain upper right lon:	-69.875
LIS run domain resolution (dx):	0.25
LIS run domain resolution (dy):	0.25

LIS parameter data file: specifies the name of the parameter input file used in the LIS run. This file will be generated by the Land Data Toolkit (LDT).

LIS parameter data file: ./lis_input.d01.nc

Soil texture data source: specifies the name of the soil texture data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

Soil texture data source: "STATSGO"

Soil fraction data source: specifies the name of the soil fraction data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

Soil fraction data source: "none"

Soil color data source: specifies the name of the soil color data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

Soil color data source: "none"

Elevation data source: specifies the name of the topographical elevation data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

Elevation data source: "none"

Slope data source: specifies the name of the topographical slope data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

Slope data source: "none"

Aspect data source: specifies the name of the topographical aspect data source used in the LIS run (This information is used to replicate the domain creation that was done in the LIS run).

```
Aspect data source: "none"
```

The following options are used for subgrid tiling based on vegetation, soils or topography.

Maximum number of surface type tiles per grid: defines the maximum surface type tiles per grid (this can be as many as the total number of vegetation/landcover types) used in the LIS simulation.

```
Maximum number of surface type tiles per grid: 1
```

Minimum cutoff percentage (surface type tiles): defines the smallest percentage (among the surface type distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (surface type tiles): 0.10
```

Maximum number of soil texture tiles per grid: defines the maximum soil texture type tiles per grid (this can be as many as the total number of soil texture types) used in the LIS simulation.

```
Maximum number of soil texture tiles per grid: 1
```

Minimum cutoff percentage (soil texture tiles): defines the smallest percentage (among the soil texture distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (soil texture tiles): 0.10
```

Maximum number of soil fraction tiles per grid: defines the maximum soil fraction tiles per grid used in the LIS simulation.

```
Maximum number of soil fraction tiles per grid: 1
```

Minimum cutoff percentage (soil fraction tiles): defines the smallest percentage (among the soil fraction distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (soil fraction tiles): 0.10
```

Maximum number of elevation bands per grid: defines the maximum elevation bands per grid used in the LIS simulation.

```
Maximum number of elevation bands per grid: 1
```

Minimum cutoff percentage (elevation bands): defines the smallest percentage (among the elevation distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (elevation bands): 0.10
```

Maximum number of slope bands per grid: defines the maximum slope bands per grid used in the LIS simulation.

```
Maximum number of slope bands per grid: 1
```

Minimum cutoff percentage (slope bands): defines the smallest percentage (among the slope distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (slope bands): 0.10
```

Maximum number of aspect bands per grid: defines the maximum aspect bands per grid used in the LIS simulation.

```
Maximum number of aspect bands per grid: 1
```

Minimum cutoff percentage (aspect bands): defines the smallest percentage (among the aspect distributions within a grid cell) for which to create a tile, used in the LIS simulation. The percentage value is expressed as a fraction.

```
Minimum cutoff percentage (aspect bands): 0.10
```

LIS output attributes file: specifies the output attributes file. This file can be specified by using the model output attributes used to for customizing the LIS model output. An extra column needs to be added in this file to specify which variables among the LIS output are to be included in the evaluation/verification.

```
LIS output attributes file: './MODEL_OUTPUT_LIST_LVT.TBL'
```

LIS surface soil layer thickness: specifies the thickness (in m) of the surface soil layer

LIS surface soil layer thickness: 0.1

LIS root zone soil layer thickness: specifies the thickness (in m) of the root zone soil layer

LIS root zone soil layer thickness: 1.0

LIS soil moisture layer thickness: specifies the thicknesses (in m) of the soil moisture layers in the LIS simulation

LIS soil moisture layer thickness: 0.1 0.3 0.6 1.0
--

LIS soil temperature layer thickness: specifies the thicknesses (in m) of the soil temperature layers in the LIS simulation

LIS soil temperature layer thickness: 0.1 0.3 0.6 1.0

7.4 Analysis options specification

This section of the config file specifies the type of analysis to be conducted during the verification/evaluation. Note that some options are only available in certain running modes.

Apply external mask: Specifies whether to apply an external mask in limiting the analysis to a selected set of data points. Note that undefined value is considered to be the value used for omitting grid points. All values other than 'undefined values' (e.g. -9999.0) are considered as valid.

Acceptable values are:

Value	Description
0	Do not apply external mask
1	Apply external, temporally varying mask
2	Apply fixed mask

Apply external mask: 0

External mask directory: Specifies the name of the data mask file/directory. If the mask varies temporally, then this option specifies the top-level directory containing data mask. Note that the mask files are expected to be in binary, sequential access format.

External mask directory: none

Compute ensemble metrics: specifies whether to compute ensemble-based metrics or not. If this option is turned on, then all the traditional (non-ensemble) metrics will be turned off.

Acceptable values are:

Value	Description
0	Do not compute
1	compute ensemble metrics

```
Compute ensemble metrics:      0
```

Compute information theory metrics: specifies whether to compute information theory-based metrics or not. If this option is turned on, then the ensemble and traditional metrics will be turned off.

Acceptable values are:

Value	Description
0	Do not compute
1	compute information theory metrics

```
Compute information theory metrics:      0
```

Metrics attributes file: specifies the attributes of the metrics that are used in the LVT analysis. Section 8 describes the format of the metrics attributes file.

```
Metrics attributes file:    './METRICS.TBL'
```

Observation count threshold: Specifies the number of observations to be used as the minimum threshold for computing statistics. Grid points with observation count less than this value will be ignored.

Acceptable values are 0 or higher

```
Observation count threshold:      50
```

Temporal averaging interval: Specifies (in seconds) the temporal averaging interval of the LIS output and observation data.

```
Temporal averaging interval:      "1da"
```

Stats output directory: Specifies the top-level directory where the output from the analysis is to be written.

```
Stats output directory:      ./STATS
```

Stats output interval: Specifies the frequency (in seconds) of the analysis output.

Note that the stats output interval is simply a setting for specifying the frequency of LVT outputs. If the stats output interval is different from (greater than) the time averaging interval, no additional averaging will be performed between the time averaging intervals.

Stats output interval:	"1da"
-------------------------------	-------

Time series location file: Specifies the name of the file which lists the locations and regions in the domain where ASCII time series data are to be derived. The locations can be specified in three different formats: (1) using the lat/lon values (2) using the column/row indices and (3) using the tile indices. A sample file is shown below:

```
#Number of locations
2
#Location style (1-lat/lon, 2-col/row, 3-tile)
1
#Location name, (next line) SW-lat, SW-lon, NE-lat, NE-lon,
min number of grid points
WEST_US
40 -130 50 -110 5
HIGH_PLAINS_US
43 -110 49 -100 2
.....
.....
```

If the location style is 2, the user specifies the column and row indices for the bounding boxes, instead of the corner lat/lon values. A sample file with location style 2 is shown below:

```
#Number of locations
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
2
#Location name, (next line) SW-col, SW-row, NE-col, NE-row,
min number of grid points
WEST_US
1 1 20 30 5
EAST_US
1 1 10 10 5
.....
.....
```

If the location style is 3, the user specifies the tile indices for specifying the bounds (starting tile index and ending tile index). A sample file with location style 3 is shown below:

```
#Number of locations
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
3
#Location name, (next line) Start index, Ending index,
min number of grid points
WEST_US
1 20 5
EAST_US
1 10 5
.....
.....
```

Please see the sample TS_LOCATIONS.TXT file for an example in format (1)

Time series location file:	./TS_LOCATIONS.TXT
----------------------------	--------------------

Variable-based stratification: Specifies if the errors are to be stratified using one of the model output variables. The errors will be stratified into two levels (1) where the values of the stratification variable falls above the specified threshold and (2) where the values of the stratification variable falls below the specified threshold.

Acceptable values are:

Value	Description
0	Do not stratify
1	Stratify errors

Variable-based stratification: 0

Stratification variable: Specifies the name of the variable to be used in the stratification

Stratification variable: SWdown_f

Stratification threshold: Specifies the minimum value to be used as the stratification threshold.

Stratification threshold:	1.0
---------------------------	-----

Confidence interval (%): Specifies the confidence interval threshold (in percentage) of the computed statistics

Confidence interval (%):	95
--------------------------	----

External data-based stratification: Specifies if the errors are to be stratified based on an external (static) dataset (e.g. landcover, elevation,etc.)
The associated attributes file specifies the stratification details

Acceptable values are:

Value	Description
0	Do not stratify
1	Stratify errors

External data-based stratification:	0
-------------------------------------	---

Stratification attributes file: Specifies the name of the file which lists the details of the stratification. The format of the time series location file is as follows:

```
#Number of stratification data sources
3
#Stratification data files
srtm_elev1km.1gd4r
srtm_slope1km.1gd4r
srtm_aspect1km.1gd4r
#stratification variable name
ELEV
SLOPE
ASPECT
#Max min values
7000 1.0 6
500 0.0 0
#number of bins
12 12 12
```

Stratification attributes file:	./strat_attribs.txt
---------------------------------	---------------------

Seasonal cycle interval type: Specifies the interval type for average seasonal cycle computations (when enabled in the METRICS.TBL file)

Acceptable values are:

Value	Description
monthly	monthly seasonal cycles
3 monthly	3-monthly seasonal cycles (DJF,MAM,JJA,SON)
6 monthly	6-monthly seasonal cycles
yearly	yearly seasonal cycles

```
Seasonal cycle interval type: "monthly"
```

Seasonal cycle minimum count threshold: Specifies minimum number of points to be used in computing the average seasonal cycle computations.

```
Seasonal cycle minimum count threshold: 10
```

Average diurnal cycle minimum count threshold: Specifies minimum number of points to be used in computing the average diurnal cycle computations.

```
Average diurnal cycle minimum count threshold: 10
```

7.5 Observation sources

This section of the config file specifies the details of the observational sources.

LIS optUE restart file: the name of the file that specifies the parameter distributions LVT expects this information to be provided through the uncertainty estimation algorithm restart file. Note that this option need to be specified only if ensemble cross correlation metric is enabled.

```
LIS optUE restart file: MCSIM.001.MCSIMrst
```

LIS optUE restart file: the name of the file that specifies the parameter distributions LVT expects this information to be provided through the uncertainty estimation algorithm restart file. Note that this option need to be specified only if ensemble cross correlation metric is enabled.

```
LIS optUE restart file: MCSIM.001.MCSIMrst
```

LIS optUE number of model parameters: specifies the number of model parameters in the uncertainty estimation algorithm restart file. Note that this option need to be specified only if ensemble cross correlation metric is enabled.

```
LIS optUE number of model parameters: 4
```

7.5.1 LIS LSM output as the observation

LISlsmObs model name: name of the model used in the simulation. Acceptable values are:

Value	Description
NOAH	Noah land surface model
CLSM	Catchment land surface model

LISlsmObs domain type: specifies the domain type used in generating the output

LISlsmObs nest index: specifies the nest index of the domain

LISlsmObs experiment code: specifies the experiment code number used in the simulation

The domain should be specified, based on the domain type.

LISlsmObs model output attributes file: specifies the model output attribute file used for generating the output

```
LISlsmObs model name:      CLSM
LISlsmObs domain type:        1
LISlsmObs nest index:        1
LISlsmObs experiment code:    111
LISlsmObs output naming style: 1
LISlsmObs output directory:   ./CLSM/OUTPUT
LISlsmObs domain lower left lat: 30.5
LISlsmObs domain lower left lon: -124.5
LISlsmObs domain upper right lat: 50.5
LISlsmObs domain upper right lon: -75.5
LISlsmObs domain resolution (dx): 1.0
LISlsmObs domain resolution (dy): 1.0
LISlsmObs model output attributes file:  './CLSM_OUTPUT_LIST.TBL'
```

7.5.2 CEOP station observations

CEOP undefined value: specifies the undefined value used in CEOP data

CEOP metadata file: specifies the file that lists the metadata for the CEOP stations.

CEOP read surface meteorology data: specifies whether to read the surface meteorology data (.true. or .false.)

CEOP read flux data: specifies whether to read the surface fluxes data (.true. or .false.)

CEOP read soil moisture and temperature data: specifies whether to read the soil moisture and temperature data (.true. or .false.)

CEOP soil moisture layer weights: specifies the vertical interpolation weights for soil moisture

CEOP soil temperature layer weights: specifies the vertical interpolation weights for soil temperature

CEOP surface meteorology data file: specifies the surface meteorology data

file

CEOP flux data file: specifies the flux data file

CEOP soil temperature and moisture data file: specifies the soil temperature and moisture data file.

CEOP undefined value:	-999.99
CEOP metadata file:	./bon.mdata
CEOP read surface meteorology data:	.true.
CEOP read flux data:	.true.
CEOP read soil moisture and temperature data:	.true.
CEOP soil moisture layer weights:	3 2 6 10 22 42
CEOP soil temperature layer weights:	3 2 6 10 22 42
CEOP surface meteorology data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231.sfc
CEOP flux data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231.flx
CEOP soil temperature and moisture data file:	./CEOP/GAPP/GAPP_Bondville_20021001_20041231

7.5.3 ISCCP land surface temperature observations

ISCCP Tskin data directory: specifies the location of the ISCCP land surface temperature data

ISCCP Tskin data directory:	'./ISCCP'
-----------------------------	-----------

7.5.4 SCAN soil moisture observations

SCAN observation directory: specifies the location of the SCAN soil moisture observation data

SCAN number of stations: specifies the number of SCAN stations used in the analysis

SCAN coord file: specifies the file that lists the location of the SCAN stations. The format of the metadata file is as follows: SCAN state, station id, station lat, station lon, elevation

AL 2058 34.43 -87 6 633
AR 2030 34.85 -91.88 6 250
AR 2091 34.28 -91.35 6 197
AZ 2026 31.73 -110.05 7 4500
GA 2013 33.88 -83.43 5 770
GA 2027 31.5 -83.55 5 350
....
....

SCAN observation directory:	./SCAN/
SCAN number of stations:	37
SCAN coord file:	./SCAN_coord.txt

7.5.5 COOP snow depth observations

COOP observation directory: specifies the location of the COOP snow depth observation data

COOP coord file: specifies the file that lists the location of the COOP stations. The format of the station list is as follows:

010008	ABBEVILLE	31.570	-84.752
010116	ALABASTER SHELBY CO AP	33.178	-85.218
010140	ALBERTA	32.232	-86.589
.....			
.....			

COOP metadata file: specifies the file that lists the metadata for the COOP stations. The format of the metadata file is as follows:

```
#nstns udef    syr    smo    sda    smn    eyr    eda    emo    ehr    emn    ts
10395 -9999.0 2007 11 01 01 00 2008 06 01 00 00 3600
#nstates
47
#state names
AL
AR
AZ
CA
CO
CT
FL
GA
IA
ID
IL
IN
KS
KY
LA
MA
MD
ME
MI
```

MN
MO
MS
MT
NC
ND
NE
NH
NJ
NM
NV
NY
OH
OK
OR
PA
RI
SC
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY

COOP observation directory:	./COOP
COOP coord file:	./COOP/COOP_stnlist.dat
COOP metadata file:	./COOP/COOP_mdata

7.5.6 SURFRAD radiation observations

SURFRAD observation directory: specifies the location of the SURFRAD radiation data

SURFRAD observation directory: .../SURFRAD
--

7.5.7 Walnut Gulch PBMR soil moisture observations

WG PBMR observation directory: specifies the location of the Walnut Gulch PBMR soil moisture observation data

WG PBMR site index: specifies the station being used

WG PBMR observation directory:	./WG PBMR
WG PBMR coord file:	1

7.5.8 SNOTEL SWE observations

SNOTEL observation directory: specifies the location of the SNOTEL SWE observation data

SNOTEL coord file: specifies the file that lists the location of the SNOTEL stations. The format of the station list is as follows:

AZ	BAKER BUTTE	11R06S	308	34.450	-111.400
AZ	BAKER BUTTE SMT	11R07S	1140	34.450	-111.367
AZ	BALDY	09S01S	310	33.967	-109.500
AZ	BEAVER HEAD	09S06S	902	33.683	-109.200
.....					
.....					

SNOTEL metadata file: specifies the file that lists the metadata for the SNOTEL stations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time data, timestep  
712 -9999.0 2007 01 01 00 2008 12 31 00 00 86400
```

SNOTEL observation directory:	./SNOTEL
SNOTEL coord file:	./SNOTEL/SNOTEL_CONUS_list.txt
SNOTEL metadata file:	./SNOTEL/SNOTEL_mdata

7.5.9 GSOD snow depth observations

GSOD observation directory: specifies the location of the GSOD snow depth observation data

GSOD coord file: specifies the file that lists the location of the GSOD stations. The format of the station list is as follows:

000000 99999 NYGGBUKTA GREENLAND- STA	GL GL	+73483 +021567 +00030
000010 99999 JAN HAYEN	NO NO	+70983 -007700 +00229
000020 99999 ISFJORD RADIO SPITZBERGEN	NO NO	+78067 +013633 +00079
000030 99999 BJORNOYA BARENTS SEA	NO NO	+74467 +019283 +00290

000040 99999 VAROO	NO NO	+70367 +031100 +00119
000050 99999 INGOY	NO NO	+71067 +024150 +00040
.....		
.....		

GSOD metadata file: specifies the file that lists the metadata for the GSOD stations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time data, timestep
30727 -9999.0 2007 11 01 01 00 2008 06 01 00 00 86400
```

GSOD observation directory:	./GSOD
GSOD coord file:	./GSOD/GSOD_CONUS_list.txt
GSOD metadata file:	./GSOD/GSOD_mdata

7.5.10 LSWG Tb observations

LSWG Tb observation filename: specifies the name of the LSWG filename containing Brightness Temperature (Tb) observations

LSWG Tb satellite name: specifies the name of satellite – same as what's used in CRTM

LSWG Tb data format: 0 for AMSR-E, 1-for AMSU **LSWG Tb metadata file:** specifies the file that lists the metadata for LSWG Tb observations. The format of the metadata file is as follows:

```
#nstns, undef, starting time, ending time, timestep (mins)
1 -1 2006 07 01 10 00 2007 06 30 17 00 3600
#LIS channel data index in file
1 1
2 2
3 3
4 4
5 5
6 6
7 7
8 8
9 9
10 10
11 11
12 12
13 13
14 14
15 15
```

LSWG Tb include cloud masking: specifies if data is to be ignored in the presence of clouds (0-do not ignore, 1-ignore) **LSWG Tb cloud mask file:** specifies the name of the cloud mask file **LSWG Tb cloud mask column:** ?? **LSWG Tb cloud mask threshold(%):** specifies the threshold below which clouds can be ignored (used only if cloud masking is enabled).

```
LSWG Tb observation filename:      './_LSWG/C3VP.txt'
LSWG Tb satellite name:          'N18_'
LSWG Tb data format:             1
LSWG Tb metadata file:          ./C3VP_mdata
LSWG Tb include cloud masking:   1
LSWG Tb cloud mask file:        ./cloud_mask.txt
LSWG Tb cloud mask column:      ???
LSWG Tb cloud mask threshold(%): 75
```

7.5.11 FMI SWE observations

FMI observation directory: specifies the location of the FMI snow course data

```
FMISWE observation directory:      ./FMI_SWE
```

7.5.12 CMC's daily snow depth observations

CMC SNWD observation directory: specifies the location of the CMC snow depth observation data

CMC SNWD metadata file: specifies the file that lists the metadata for the CMC snow depth data. The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

```
CMC SNWD observation directory:      ./CMC_data
CMC SNWD metadata file:            ./CMC_data/CMC_SNWD_mdata
```

7.5.13 SNODAS snow analysis data

SNODAS observation directory: specifies the location of the SNODAS data

SNODAS metadata file: specifies the file that lists the metadata for the SNODAS. The format of the metadata file is as follows:

```
#undef, starting time, ending time data, timestep
-9999.0 2007 11 01 00 00 2008 12 30 00 00 86400
```

SNODAS observation directory:	./SNODAS
SNODAS metadata file:	./SNODAS/SNODAS_mdata

7.5.14 NASA AMSR-E soil moisture retrievals

NASA AMSR-E soil moisture observation directory: specifies the location of the standard (NASA) AMSR-E soil moisture retrievals

NASA AMSRE soil moisture observation directory: ./NASA_AMSRE
--

7.5.15 NESDIS AMSR-E soil moisture retrievals

NESDIS AMSR-E soil moisture observation directory: specifies the location of the NESDIS AMSR-E soil moisture retrievals

NESDIS AMSRE soil moisture observation directory: ./NESDIS_AMSRE
--

7.5.16 VU AMSR-E soil moisture retrievals

VU AMSR-E soil moisture observation directory: specifies the location of the University of Amsterdam (Vrije Universiteit - VU) AMSR-E soil moisture retrievals

VU AMSRE soil moisture observation directory: ./VU_AMSRE
--

7.5.17 AMMA station observations

AMMA observation directory: specifies the location of the AMMA in-situ observations. AMMA static txt file list: specifies the file with the station file names in text format (.txt)

A sample static txt file list is shown below:

```
12
201006140332132535.csv
201006140337342536.csv
201006140347082537.csv
201006140348592538.csv
201006140351382539.csv
201006140358582540.csv
201006140400532541.csv
201006140402202542.csv
201006140640302543.csv
201006140641442544.csv
201006140642422545.csv
```

201006140643372546.csv

AMMA static netcdf file list: specifies the file with the station file names in netcdf format

A sample static txt file list is shown below:

```
10
ceh-aws_agoufou_20050414.nc
ceh-aws_bamba_20050426.nc
ceh-aws_banizoumbou_20051115.nc
ceh-aws_belifoungou_20051111.nc
ceh-aws_bira_20051113.nc
ceh-aws_hedgerit_20050415.nc
ceh-aws_kelema_20050416.nc
ceh-aws_nalohou_20051111.nc
ceh-aws_pobe_20050220.nc
ceh-aws_wankama_20051117.nc
```

AMMA soil moisture layer weights: normalized weights to be applied for root zone computations of soil moisture **AMMA soil temperature layer weights:** normalized weights to be applied for root zone computations of soil temperature

AMMA observation directory:	./AMMA/
AMMA static txt file list:	amma_static_txtfiles.txt
AMMA static netcdf file list:	amma_static_ncfiles.txt
AMMA soil moisture layer weights:	0.1875 0.1875 0.625 0.0 0.0
AMMA soil temperature layer weights:	0.1875 0.1875 0.625 0.0 0.0

7.5.18 Ameriflux station observations

Ameriflux observation directory: specifies the location of the Ameriflux datasets. **Ameriflux station list file:** specifies the file that lists the location of the Ameriflux stations. The format of the station list is as follows:

```
#nstns
76
#stnname; location name; lat; lon; SWC1 depth; SWC2 depth; TS1 depth; TS2 depth
ARM_SGP_Burn; USARb; 35.5497; -98.0402; 10; 30; 5; 15
ARM_SGP_Control; USARc; 35.5465; -98.0401; 10; 30; 5; 15
ARM_SGP_Main; USARM; 36.6058; -97.4888; 5; 25; 5; 15
Atqasuk; USAtq; 70.4696; -157.4089; -1; -1; 0; 5
Audubon_Grasslands; USAud; 31.5907; -110.5092; 10; 20; 2; 4
Austin_Cary; USSP1; 29.7381; -82.2188; -1; -1; 0; 5
```

```

Barrow; USBrw; 71.3225; -156.6259; -1; -1; 0; 5
Bartlett_Experimental_Forest; USBar; 44.0645; -71.2881; 10; -1; 5; -1
Blodgett_Forest; USBlo; 38.8953; -120.6328; 10; 20; 5; 10
Bondville; USB01; 40.0062; -88.2904; 5; 20; 2; 4
.....
.....
```

Ameriflux observation directory:	.../AmeriFlux
Ameriflux station list file:	.../AmeriFlux/Ameriflux_stns.txt

7.5.19 ARM station observations

ARM observation directory: specifies the location of the ARM datasets
ARM site identifier name: specifies the text identifier (e.g. sgp, twp, nsa, etc.)
ARM station list file: specifies the file that lists the location of the ARM stations. The format of the station list is as follows:

ARM use BAEBBR data: specifies if to use the BAEBBR data or not
ARM use EBBR data: specifies if to use the EBBR data or not
ARM use ECOR data: specifies if to use the ECOR data or not
ARM use SWATS data: specifies if to use the SWATS data or not
ARM use SMOS data: specifies if to use the SMOS data or not

```

#nstns
22
#stnname; lat; lon
E1; 38.202; -99.316
E2; 38.306; -97.301
E3; 38.201; -95.597
E4; 37.953; -98.329
E5; 38.114; -97.513
E6; 37.842; -97.020
E7; 37.383; -96.180
E8; 37.333; -99.309
E9; 37.133; -97.266
.....
.....
```

ARM observation directory:	.../ARM_SGP
ARM site identifier name:	sgp
ARM station list file:	.../ARM_SGP/sgp_stns.txt
ARM use BAEBBR data:	1
ARM use EBBR data:	1
ARM use ECOR flux data:	1

```
ARM use SWATS data:      1  
ARM use SMOS data:       1
```

7.5.20 SMOSREX in-situ soil moisture observations

SMOSREX observation filename: specifies the name of the SMOSREX observation filename. Currently this plugin only handles a single observation location.

```
SMOSREX observation filename: ./SMOSREX/Toulouse_SMOSREX.dat
```

7.5.21 AGRMET data

AGRMET data directory: specifies the location of the AGRMET data.

```
AGRMET data directory: ./AGRMET_data/
```

7.5.22 GlobSnow data

GlobSnow data directory: specifies the location of the GlobSnow data.

```
GlobSnow data directory: ../GlobSnow
```

7.5.23 SNODEP data

SNODEP observation directory: specifies the location of the SNODEP observation data.

```
SNODEP observation directory: ./SNODEP
```

7.6 DA diagnostics analysis

This section of the config file specifies the specialized options to analyze the data assimilation diagnostics. These options are employed for runmode="DA statistics processing"

Compute Innovation Distribution: Specifies if innovation distribution analysis (computing mean and variance) is to be computed.

Acceptable values are:

Value	Description
0	Do not compute
1	Compute

```
Compute Innovation Distribution:          1  
Compute Analysis Gain:                  0  
Number of state variables in the DA update: 4
```

7.7 Observation processing

This runmode is used to convert a given observational data into a "LIS style". Once the data is converted, intercomparisons with any observation-plugin in LVT can be made.

No specialized options are necessary, except that the 'LIS Output directory:' corresponds to the directory where the converted data will be written.

7.8 DA observation analysis

This runmode is used to conduct analysis of observations used in the DA assimilation instance. LIS DA subsystem generates processed (interpolated, QC'd) estimates of input observations. This runmode enables analysis of such data.

No specialized options are necessary, except specifying the 'LIS output attributes file:' option to correspond to the DA output. For example, if the DA instance generates estimates of a single variable (say SWE) then specify the LIS output attributes file such that (only) SWE is present in the (LIS) output file. In other words, column number 2 should indicate 1 for SWE variable and 0 for every other variable. If multiple observation types are present in the DA output, then column number 2 should be appropriately modified.

7.9 Optimization/Uncertainty Estimation output analysis

This section of the config file specifies the specialized options to analyze outputs from Optimization/Uncertainty Estimation algorithms.

The following options are for analyzing optimization/uncertainty estimation data output **OptUE algorithm used:** specifies the index of the optimization/uncertainty estimation algorithm used

Acceptable values are:

Value	Description
1	Levenberg- Marquardt
2	Genetic Algorithm
3	SCE-UA
4	MCSIM
5	MCMC
6	DEMC

```
OptUE algorithm used: 2
```

OptUE Decision Space Attributes File: lists the decision space attributes file used in the LIS optimization/uncertainty estimation integration.

```
OptUE Decision Space Attributes File: ./GArun/noah_sm_decspace.txt
```

Number of Iterations: Number of generations used in the optimization/uncertainty estimation algorithm.

OptUE Number of Iterations:	20
-----------------------------	----

Compute OptUE time series: specifies if a time series of OptUE run output data is to be generated (0-no, 1-yes)

OptUE Compute time series:	1
----------------------------	---

OptUE Time series location file: specifies the file which lists the locations in the domain where the time series data are to be extracted. The format of the time series location file is as follows:

```
#Number of locations
1
#Location style (1-lat/lon, 2-col/row, 3-tile)
2
#mask filename
none
#site name
Site1
244 236
```

OptUE Time series location file:	./STN_LOCATIONS.DAT
----------------------------------	---------------------

8 Configuration of metrics

This section defines the specification of various metrics in LVT. This file is specified in a space delimited column format. Each row consists of the following entries:

Name: Name of the metric

Use option: determines whether to use this metric. When enabled, the metric will be computed through the duration of the evaluation and a final file will be written out

Acceptable values are:

Value	Description
0	do not use the metric
1	use the metric

Time option: specifies whether to compute the metric in time, at the specified stats output intervals. Acceptable values are:

Value	Description
0	do not compute the metric
1	compute the metric

Temporal output: determines whether to write (gridded) metric files at the specified stats output intervals. The 'Time option' must also be enabled when this option is enabled.

Acceptable values are:

Value	Description
0	Do no write
1	write

Extract time series: determines whether to extract (ASCII) time series files for the metric, at each sub-domains specified in the time series location file.

Acceptable values are:

Value	Description
0	Do no write
1	write

Threshold: The threshold value to be used in computing the metric. Note that this is used only for the categorical metrics.

Compute average seasonal cycle: determines whether to generate the average seasonal cycle of the metric (for each domain specified in the time series location file).

Acceptable values are:

Value	Description
0	Do no generate
1	generate

Compute average diurnal cycle: determines whether to generate the average diurnal cycle of the metric (for each domain specified in the time series location file).

Acceptable values are:

Value	Description
0	Do no generate
1	generate

#name	total	in-time	writeTS	extractTS	threshold	SC	ADC	short_name
Mean:	1	1	0	1	-9999.0	0	0	#Mean
Standard deviation:	0	0	0	0	-9999.0	0	0	#Std
RMSE:	0	0	0	0	-9999.0	0	0	#RMSE
Bias:	0	0	0	0	-9999.0	0	0	#Bias
ubRMSE:	0	0	0	0	-9999.0	0	0	#ubRMSE
Mean absolute error:	0	0	0	0	-9999.0	0	0	#MAE
Anomaly RMSE:	0	0	0	0	-9999.0	0	0	#ARMSE
Anomaly correlation:	0	0	0	0	-9999.0	0	0	#ARMSE
Raw correlation:	0	0	0	0	-9999.0	0	0	#RCORR
Probability of detection (PODy):	0	0	0	0	0.1	0	0	#PODy
Probability of detection (PODn):	0	0	0	0	0.1	0	0	#PODn
False alarm ratio (FAR):	0	0	0	0	0.1	0	0	#FAR
Probability of false detection (POFD):	0	0	0	0	0.1	0	0	#POFD
Critical success index (CSI):	0	0	0	0	0.1	0	0	#CSI
Accuracy measure (ACC):	0	0	0	0	0.1	0	0	#ACC
Frequency bias (FBIAS):	0	0	0	0	0.1	0	0	#FBIAS
Equitable threat score (ETS):	0	0	0	0	0.1	0	0	#ETS
Area metric:	0	0	0	0	-9999.0	0	0	#Area
Nash sutcliffe efficiency:	0	0	0	0	-9999.0	0	0	#NSE
Ensemble Mean:	1	1	0	1	-9999.0	0	0	#ensmean
Ensemble Standard deviation:	1	1	0	1	-9999.0	0	0	#ensstd
Ensemble Likelihood:	1	1	0	1	-9999.0	0	0	#ensll
Ensemble cross correlation:	1	1	0	1	-9999.0	0	0	#ensxcorr
Metric entropy:	0	0	0	0	-9999.0	0	0	#mentropy
Information gain:	0	0	0	0	-9999.0	0	0	#igain
Fluctuation complexity:	0	0	0	0	-9999.0	0	0	#fcomplexity
Effective complexity:	0	0	0	0	-9999.0	0	0	#ecomplexity

Wavelet stat:	0	0	0	0	-9999.0	0	0	#waveletstat
Hausdorff norm:	0	0	0	0	-9999.0	0	0	#Hnorm
Standard Precipitation Index:	0	0	0	0	-9999.0	0	0	#SPI
Standard Runoff Index:	0	0	0	0	-9999.0	0	0	#SRI
Stanardized Soil Water Index:	0	0	0	0	-9999.0	0	0	#SSWI
Percentile:	0	0	0	0	-9999.0	0	0	#Percentile

9 Model Output Specifications

This section defines the specification of the model output from LIS. This file is specified in a space delimited column format. Each row consists of the following entries:

Short Name ALMA compliant short name of the variable.

Use option determines whether to write the variable. Acceptable values are:

Value	Description
0	do not write the variable
1	write the variable

Units the desired unit of the output variable.

Time Average option determines how temporally process the variable. Acceptable values are:

Value	Description
0	Instantaneous output
1	Time averaged output
2	Instantaneous and Time averaged output
3	Accumulated output

Min/Max option determines whether to record minimum and maximum values for the variable. Acceptable values are:

Value	Description
0	Do no compute minimum and maximum values
1	Do compute minimum and maximum values

Number of vertical levels The number of vertical levels corresponding to the variable.

grib ID The grib ID to be used for the variable if output is written in grib1 format.

grib scale factor The grib scale factor to be used for the variable if output is written in grib1 format.

Use in LVT option determines whether to include the variable in the LVT analysis. Acceptable values are:

Value	Description
0	do not include the variable
1	include the variable

Note that this is a full list of output variables. Not all models support all these variables. You must check the source code to verify that the model you want to run supports the variables that you want to write.

```
#short_name select? units timeavg? vert.levels gribid longname
#Energy balance components
Swnet:      0 W/m2  1 0 0 1 111 10 0 # Net Shortwave Radiation (W/m2)
Lwnet:      0 W/m2  1 0 0 1 112 10 0 # Net Longwave Radiation (W/m2)
Qle:        0 W/m2  1 0 0 1 121 10 0 # Latent Heat Flux (W/m2)
Qh:         0 W/m2  1 0 0 1 122 10 0 # Sensible Heat Flux (W/m2)
Qg:         0 W/m2  1 0 0 1 155 10 0 # Ground Heat Flux (W/m2)
Qf:         0 W/m2  1 0 0 1 229 10 0 # Energy of fusion (W/m2)
Qv:         0 W/m2  1 0 0 1 134 10 0 # Energy of sublimation (W/m2)
Qa:         0 W/m2  1 0 0 1 136 10 0 # Advective Energy (W/m2)
Qtau:       0 W/m2  1 0 0 1 135 10 0 # Momentum flux (N/m2)
DelSurfHeat: 0 W/m2  1 0 0 1 137 10 0 # Change in surface heat storage (J/m2)
DelColdCont: 0 W/m2  1 0 0 1 138 10 0 # Change in snow cold content (J/m2)
BR:          0 -     1 0 0 1 138 10 0 # Change in snow cold content (J/m2)
EF:          0 -     1 0 0 1 138 10 0 # Change in snow cold content (J/m2)

#Water balance components
Snowf:      0 kg/m2s 1 0 0 1 161 10000 0 # Snowfall rate (kg/m2s)
Rainf:      0 kg/m2s 1 0 0 1 162 10000 0 # Rainfall rate (kg/m2s)
RainfConv:   0 kg/m2s 1 0 0 0 163 10000 0 # Convective Rainfall rate (kg/m2s)
TotalPrecip: 0 kg/m2s 1 0 0 0 164 10000 0 # Total Precipitation rate (kg/m2s)
Evap:        1 kg/m2s 1 0 0 1 57 10000 0 # Total Evapotranspiration (kg/m2s)
Qs:          1 kg/m2  1 0 0 1 235 10000 0 # Surface runoff (kg/m2s)
Qrec:        0 kg/m2  1 0 0 0 143 10000 0 # Recharge (kg/m2s)
Qsb:         1 kg/m2  1 0 0 1 254 10000 0 # Subsurface runoff (kg/m2s)
Qsm:         1 kg/m2  0 0 0 1 99 10000 0 # Snowmelt (kg/m2s)
Qfz:         0 kg/m2s 1 0 0 0 146 10000 0 # Refreezing of water in the snowpack (kg/m2s)
Qst:         0 kg/m2s 1 0 0 0 147 10000 0 # Snow throughfall (kg/m2s)
DelSoilMoist: 0 kg/m2  1 0 0 0 148 10000 0 # Change in soil moisture (kg/m2)
DelSWE:       0 kg/m2  1 0 0 0 149 1000 0 # Change in snow water equivalent (kg/m2)
DelSurfStor:  0 kg/m2  1 0 0 0 150 1000 0 # Change in surface water storage (kg/m2)
DelIntercept: 0 kg/m2  1 0 0 0 151 1000 0 # Change in interception storage (kg/m2)
RHMin:       0 -     0 0 0 0 51 10 0 # Minimum 2 meter relative humidity (-)

#Surface State Variables
SnowT:       0 K      1 0 0 1 152 10 0 # Snow surface temperature (K)
VegT:        0 K      1 0 0 0 153 10 0 # Vegetation canopy temperature (K)
```

```

BareSoilT:    0   K      1 0 0 0 154 10 0 # Temperature of bare soil (K)
AvgSurfT:    0   K      1 0 0 1 148 10 0 # Average surface temperature (K)
RadT:        0   K      1 0 0 0 156 10 0 # Surface Radiative Temperature (K)
Albedo:       0   -      1 0 0 1 84 100 0 # Surface Albedo (-)
SWE:          1   m      0 0 0 1 65 1000 0 # Snow Water Equivalent (kg/m2)
SnowDepth:    1   m      1 0 0 1 66 1000 1 # Snow Depth (m)
Snowcover:    1   -      1 0 0 1 66 100 0 # Snow Depth (m)
SWEVeg:       0   kg/m2  1 0 0 0 159 1000 0 # SWE intercepted by vegetation (kg/m2)
SurfStor:     0   kg/m2  1 0 0 0 160 1000 0 # Surface water storage (kg/m2)
SLiqFrac:     0   -      0 0 0 0 65 1000 0 # fraction of SWE in the liquid phase
RootTemp:     0   K      1 0 0 1 65 1000 0 # fraction of SWE in the liquid phase

#Subsurface State Variables
SoilMoist:   0   m3/m3  1 0 0 4 86 1000 0 # Average layer soil moisture (kg/m2)
SoilTemp:    0   K      1 0 0 4 85 1000 0 # Average layer soil temperature (K)
SmLiqFrac:   0   kg/m2  1 1 0 0 85 100 0 # Average layer fraction of liquid moisture (-)
SmFrozFrac:  0   kg/m2  1 1 0 0 85 100 0 # Average layer fraction of frozen moisture (-)
SoilWet:     0   kg/m2  1 1 0 0 85 100 0 # Total soil wetness (-)
RelSMC:      0   m3/m3  0 0 0 0 86 1000 0 # Relative soil moistutre

#Evaporation components
PotEvap:     0   kg/m2s  1 1 0 0 166 1 0 # Potential Evapotranspiration (kg/m2s)
ECanop:       0   kg/m2s  1 1 0 0 200 1 0 # Interception evaporation (kg/m2s)
TVeg:         0   kg/m2s  1 1 0 0 210 1 0 # Vegetation transpiration (kg/m2s)
ESoil:        0   kg/m2s  1 1 0 0 199 1 0 # Bare soil evaporation (kg/m2s)
EWater:       0   kg/m2s  1 1 0 0 170 1 0 # Open water evaporation (kg/m2s)
RootMoist:   0   m3/m3  1 0 0 1 171 1 0 # Root zone soil moisture (kg/m2)
CanopInt:    0   kg/m2  1 0 0 1 223 1000 0 # Total canopy water storage (kg/m2)
EvapSnow:    0   kg/m2s  1 1 0 0 173 1000 0 # Snow evaporation (kg/m2s)
SubSnow:     0   kg/m2s  1 1 0 0 198 1000 0 # Snow sublimation (kg/m2s)
SubSurf:    0   kg/m2s  1 1 0 0 175 1000 0 # Sublimation of the snow free area (kg/m2s)
ACond:       0   m/s    1 1 0 0 179 10000 0 # Aerodynamic conductance
CCond:       0   m/s    1 0 0 0 179 1000000 0 # Canopy conductance

#Forcings
Wind_f:      0   m/s    1 0 0 1 177 10 0 # Near Surface Wind (m/s)
Rainf_f:     1   kg/m2s  1 0 0 1 162 1000 0 # Average rainfall rate
Snowf_f:     0   kg/m2s  0 1 0 0 161 1000 0 # Average snowfall rate
Tair_f:      0   K      1 0 0 1 11 10 0 # Near surface air temperature
Qair_f:      0   kg/kg   1 0 0 1 51 1000 0 # Near surface specific humidity
Psurf_f:     0   Pa     1 0 0 1 1 10 0 # Surface pressure
SWdown_f:    0   W/m2   1 0 0 1 204 10 0 # Surface incident shortwave radiation
Lwdown_f:    0   W/m2   1 0 0 1 205 10 0 # Surface incident longwave radiation

#Parameters
Landmask:    1   -  0 1 0 0 81 1 0 # Land Mask (0 - Water, 1- Land)

```

```

Landcover:    1    -  0 1 0 0 186 1 0 # Land cover
Soiltype:    0    -  0 1 0 0 187 1 0 # soil type
SandFrac:    1    -  0 1 0 0 999 1 0 # sand fraction
ClayFrac:    1    -  0 1 0 0 999 1 0 # clay fraction
SiltFrac:    1    -  0 1 0 0 999 1 0 # silt fraction
Porosity:    0    -  3 1 0 0 999 1 0 # porosity
Soilcolor:   0    -  0 1 0 0 188 1 0 # soil color
Elevation:   1    m  0 1 0 0 189 10 0 # elevation
Slope:       0    -  0 1 0 0 999 10 0 # slope
LAI:         0    -  0 1 0 0 190 100 0 # LAI
SAI:         0    -  0 1 0 0 191 100 0 # SAI
Snfralbedo: 0    -  0 1 0 0 192 100 0 # Snow free albedo
Mxsnalbedo: 0    -  0 1 0 0 192 100 0 # Max snow albedo
Greenness:   1    -  0 1 0 0 87 100 0 # Green vegetation fraction
Tempbot:    0    -  0 1 0 0 194 10 0 # bottom temperature

EBAL:        0    -  0 1 0 0 177 10 0 #Energy balance
WBAL:        0    -  0 1 0 0 177 10 0 #Water balance
EVAPBAL:    0    -  0 1 0 0 177 10 0 #Evaporation balance

Streamflow:   0    m3/s  0 1 0 0 177 10 0 #Streamflow

RTM emissivity: 0    -  0 1 0 0 177 10 0 #RTM Emissivity
RTM Tb:      0    K  0 1 0 0 177 10 0 #RTM Brightness Temperature

```

A How to verify a “non-LIS” dataset?

This section provides a description of how to convert a non-LIS data to a “LIS-style” so that verification and evaluation can be conducted using LVT.

First, an observation plugin for the dataset of interest must be developed within LVT. This plugin will handle the reading, processing and any spatial interpolation of the data and will connect the processed variables to the LVT core using the `LVT_logSingleVar` interface.

In the `lvt.config` file, specify the runmode to be “Observation processing”.

`LIS Running mode: ‘‘Observation processing’’`

Though not used, the files `METRICS.TBL`, `TS_LOCATIONS.TXT` must be provided as a placeholder. The sample files provided along with the source code (under `src/configs`) can be used.

Finally, specify the `MODEL_OUTPUT_LIST_LVT.TBL` file such that the selection option for all the variables that should appear in the reprocessed files is enabled (Note that this is the second column in the file `MODEL_OUTPUT_LIST_LVT.TBL`. The last column which specifies “Use in LVT” option is ignored in this running mode.

The processed files in the “LIS-style” will be generated in the location specified by the following option:

`Stats output directory: ./OUTPUT`

B Description of output files from LVT

This section provides a description of various output files generated during an LVT analysis.

For the purposes of illustration, consider the following parameters for an LVT analysis

- Variables : Qle , Qh
- Metrics : *MEAN and RMSE*
- LSM : *Noah 3.2*
- location (from *TS_LOCATIONS.TXT*) : *E20*
- Experiment name : *RUN*

B.0.1 METADATA files

If the LVT output format is specified as binary, then a number of METADATA files will be output. The METADATA files contain the spatial domain, grid and map projection specifications and the list of variables and the order in which they appear. For the above example, a file named *MEAN_NOAH32_E20RUN_METADATA.dat* will be created with entries such as the following:

```
DIMENSIONS
east-west          499
north-south         499

Missing value     -9999.000

GRID INFORMATION
MAP_PROJECTION: LAMBERT CONFORMAL
SOUTH_WEST_CORNER_LAT   34.42922
SOUTH_WEST_CORNER_LON   -100.6136
TRUELAT1      36.70000
TRUELAT2      36.70000
STANDARD_LON   -97.90000
DX      1.000000
DY      1.000000
VARIABLE: Qle           1
VARIABLE: COUNT_Qle      1
VARIABLE: OBS_Qle        1
VARIABLE: OBS_COUNT_Qle   1
VARIABLE: Qh             1
.....
.....
```

This file can be used to determine the order of variables written to the gridded output files.

For NETCDF output, the header of each file contains similar information.

B.0.2 Stats summary file

The LVT analysis will write out a summary file, for each computed metric with the following name: *MEAN_SUMMARY_STATS.dat*. This file can be used to not only determine the domain averaged statistics, but also the order in which variables are written to files. For the above example the file *MEAN_SUMMARY_STATS.dat* will contain entries such as the following (The columns 1 to 4 represent the location name, average value for that location, confidence interval, number of points contributing to the average):

```
-----
VAR: Qle
-----
ALL: 0.710E+02 +/- 0.492E+01 22
E1: 0.767E+02 +/- - 1
E2: 0.826E+02 +/- - 1
E3: 0.421E+02 +/- - 1
E4: 0.659E+02 +/- - 1
.....
.....

-----
VAR: OBS_Qle
-----
ALL: 0.906E+02 +/- 0.834E+02 11
E1: -0.100E+05 +/- - 0
E2: 0.670E+02 +/- - 1
E3: -0.100E+05 +/- - 0
E4: 0.496E+02 +/- - 1
.....
.....

-----
VAR: Qh
-----
ALL: 0.151E+02 +/- 0.564E+01 22
E1: 0.329E+02 +/- - 1
E2: -0.678E+01 +/- - 1
E3: 0.164E+02 +/- - 1
E4: 0.207E+02 +/- - 1
```

.....
.....

B.0.3 ASCII Time Series files

If the extract time series option is enabled for a particular metric in METRICS.TBL, then a corresponding time series file will be generated (similar files will be generated for each location in the *TS_LOCATIONS.TXT* file).

The time series files with the following names will be generated : *MEAN_E4.dat*, *RMSE_E4.dat*

The *MEAN_E4.dat* file will have entries such as the following:

```
2007 05 02 01 00 qle qle_STD qle_min qle_max qle_ensSTD qle_CI obs_qle obs_qle_STD  
obs_qle_min obs_qle_max obs_qle_ensSTD obs_qle_CI qh qh_STD qh_min qh_max qh_ensSTD  
qh_CI obs_qh obs_qh_STD obs_qh_min obs_qh_max obs_qh_ensSTD obs_qh_CI  
  
2007 05 02 02 00 qle qle_STD qle_min qle_max qle_ensSTD qle_CI obs_qle obs_qle_STD  
obs_qle_min obs_qle_max obs_qle_ensSTD obs_qle_CI qh qh_STD qh_min qh_max qh_ensSTD  
qh_CI obs_qh obs_qh_STD obs_qh_min obs_qh_max obs_qh_ensSTD obs_qh_CI  
.....  
.....
```

The columns represent Time (columns 1-5: year, month, day, hour, minute), mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qle from model (columns 6-11), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qle from observations (columns 12-17), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qh from model (columns 18-23), and mean value, spatial standard deviation, minimum, maximum, ensemble standard deviation, confidence interval of Qh from observations (columns 24-29).

If more variables are included in the analysis, then additional columns will be included for each variable (6 columns per variable).

For metrics such as RMSE (e.g. *RMSE_E4.dat*, the file entries will be as follows (note that there are no columns for observation values):

```
2007 05 02 01 00 rmse_qle rmse_qle_STD rmse_qle_min rmse_qle_max  
rmse_qle_ensSTD rmse_qle_CI  
2007 05 02 02 00 rmse_qle rmse_qle_STD rmse_qle_min rmse_qle_max  
rmse_qle_ensSTD rmse_qle_CI  
.....  
.....
```

B.0.4 Domain time Series files (Binary/NETCDF)

LVT will output a gridded/tiled output file for each chosen metric, at each stats output interval, if the 'write time series' option is enabled (in METRICS.TBL) for that metric. For the above example, files such as the following will be generated.

MEAN_TS.200705020000.d01.nc
MEAN_TS.200705030000.d01.nc
MEAN_TS.200705040000.d01.nc

RMSE_TS.200705020000.d01.nc
RMSE_TS.200705030000.d01.nc
RMSE_TS.200705040000.d01.nc

where the timestamp indicates the end time of each analysis interval. For binary output file extention of '.gs4r' will be used instead of '.nc'.

B.0.5 Final domain files (Binary/NETCDF)

LVT will output a gridded/tiled output file for each chosen metric. For the above example, two final files will be generated with filenames of *MEAN_FINAL.200705100000.d01.nc* and *RMSE_FINAL.200705100000.d01.nc*, where the timestamp indicates the end time of the LVT analysis. For NETCDF output file extention of '.gs4r' will be used instead of '.nc'.

C Cylindrical Lat/Lon Domain Example

This section describes how to compute the values for the run domain and param domain sections on a cylindrical lat/lon projection.

First, we shall generate the values for the parameter data domain. LIS' parameter data is defined on a Latitude/Longitude grid, from -180 to 180 degrees longitude and from -60 to 90 degrees latitude.

For this example, consider running at $1/4$ deg resolution. The coordinates of the south-west and the north-east points are specified at the grid-cells' centers. Here the south-west grid-cell is given by the box $(-180, -60), (-179.750, -59.750)$. The center of this box is $(-179.875, -59.875)$.¹

```
param domain lower left lat: -59.875
param domain lower left lon: -179.875
```

The north-east grid-cell is given by the box $(179.750, 89.750), (180, 90)$. Its center is $(179.875, 89.875)$.

```
param domain upper right lat: 89.875
param domain upper right lon: 179.875
```

Setting the resolution (0.25 deg) gives

```
param domain resolution dx: 0.25
param domain resolution dy: 0.25
```

And this completely defines the parameter data domain.

Next, we shall generate the values for the running domain.

If you wish to run over the whole domain defined by the parameter data domain then you simply set the values defined in the parameter domain section in the run domain section. This gives:

```
run domain lower left lat: -59.875
run domain lower left lon: -179.875
run domain upper right lat: 89.875
run domain upper right lon: 179.875
run domain resolution dx: 0.25
run domain resolution dy: 0.25
```

Now say you wish to run only over the region given by $(-97.6, 27.9), (-92.9, 31.9)$. Since the running domain is a sub-set of the parameter domain, it is also a Latitude/Longitude domain at $1/4$ deg. resolution. Thus,

```
run domain resolution dx: 0.25
run domain resolution dy: 0.25
```

Now, since the running domain must fit onto the parameter domain, the desired running region must be expanded from $(-97.6, 27.9), (-92.9, 31.9)$ to $(-97.75, 27.75), (-92.75, 32.0)$. The south-west grid-cell for the running domain is the box $(-97.75, 27.75), (-97.5, 28.0)$. Its center is $(-97.625, 27.875)$; giving

¹Note, these coordinates are ordered (longitude, latitude).

```
run domain lower left lat: 27.875  
run domain lower left lon: -97.625
```

The north-east grid-cell for the running domain is the box $(-93, 31.75), (-92.75, 32.0)$. Its center is $(-92.875, 31.875)$; giving

```
run domain upper right lat: 31.875  
run domain upper right lon: -92.875
```

This completely defines the running domain.

Note, the LIS project has defined 5 km resolution to be 0.05 deg. and 1 km resolution to be 0.01 deg. If you wish to run at 5 km or 1 km resolution, redo the above example to compute the appropriate grid-cell values.

See Figure 1 for an illustration of adjusting the running grid. See Figures 2 and 3 for an illustration of the south-west and north-east grid-cells.

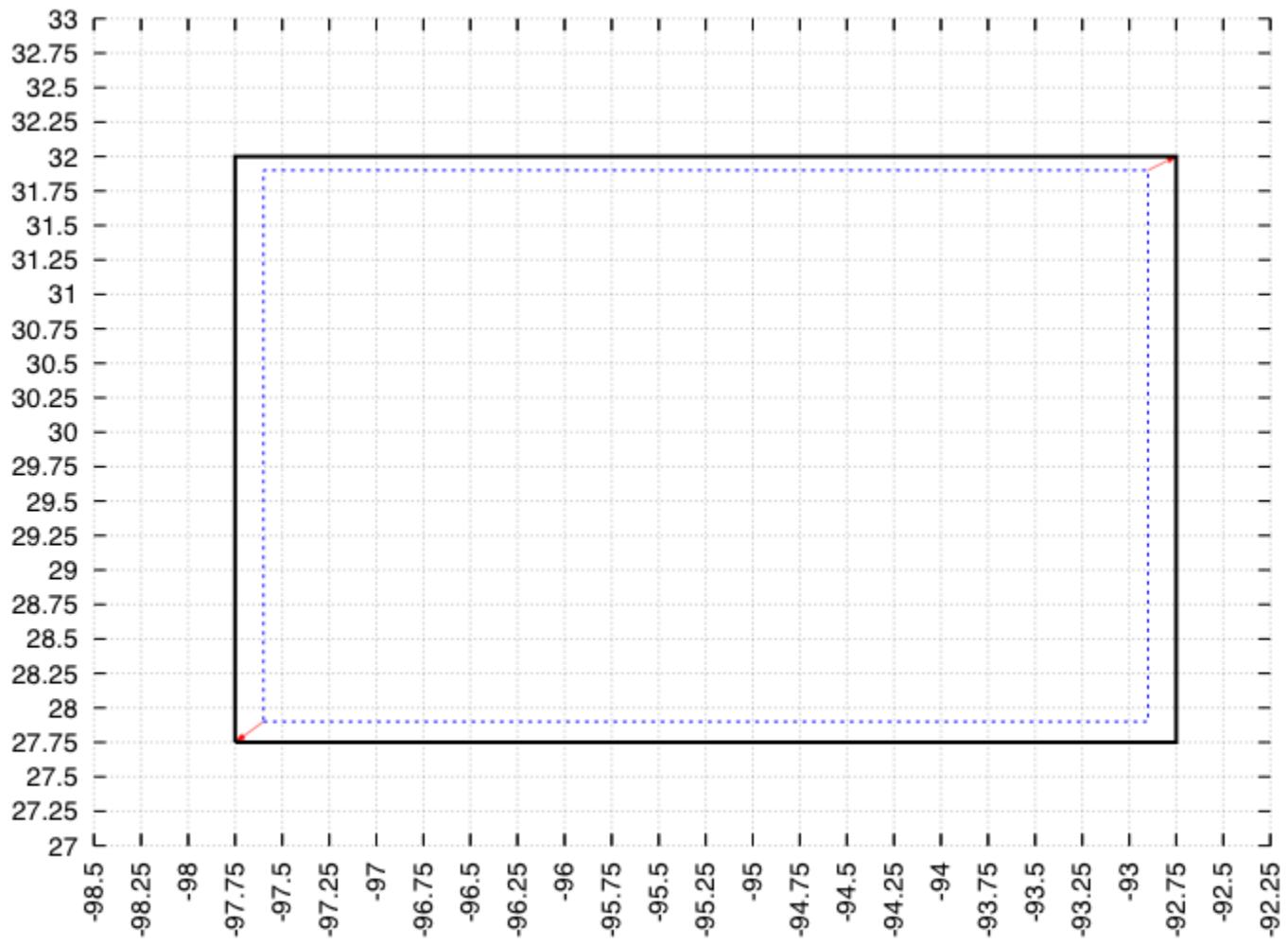


Figure 1: Illustration showing how to fit the desired running grid onto the actual grid

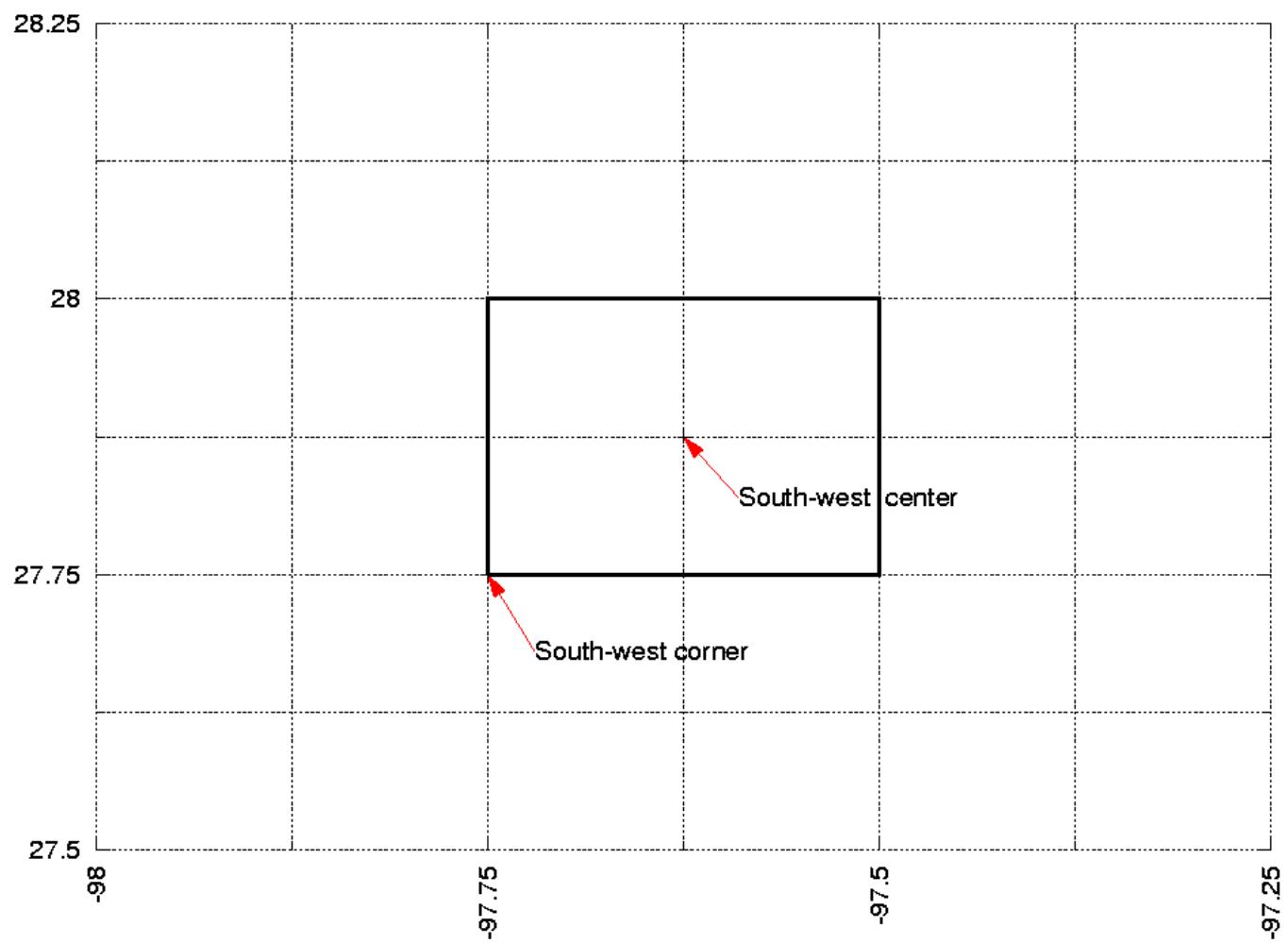


Figure 2: Illustration showing the south-west grid-cell corresponding to the example in Section C

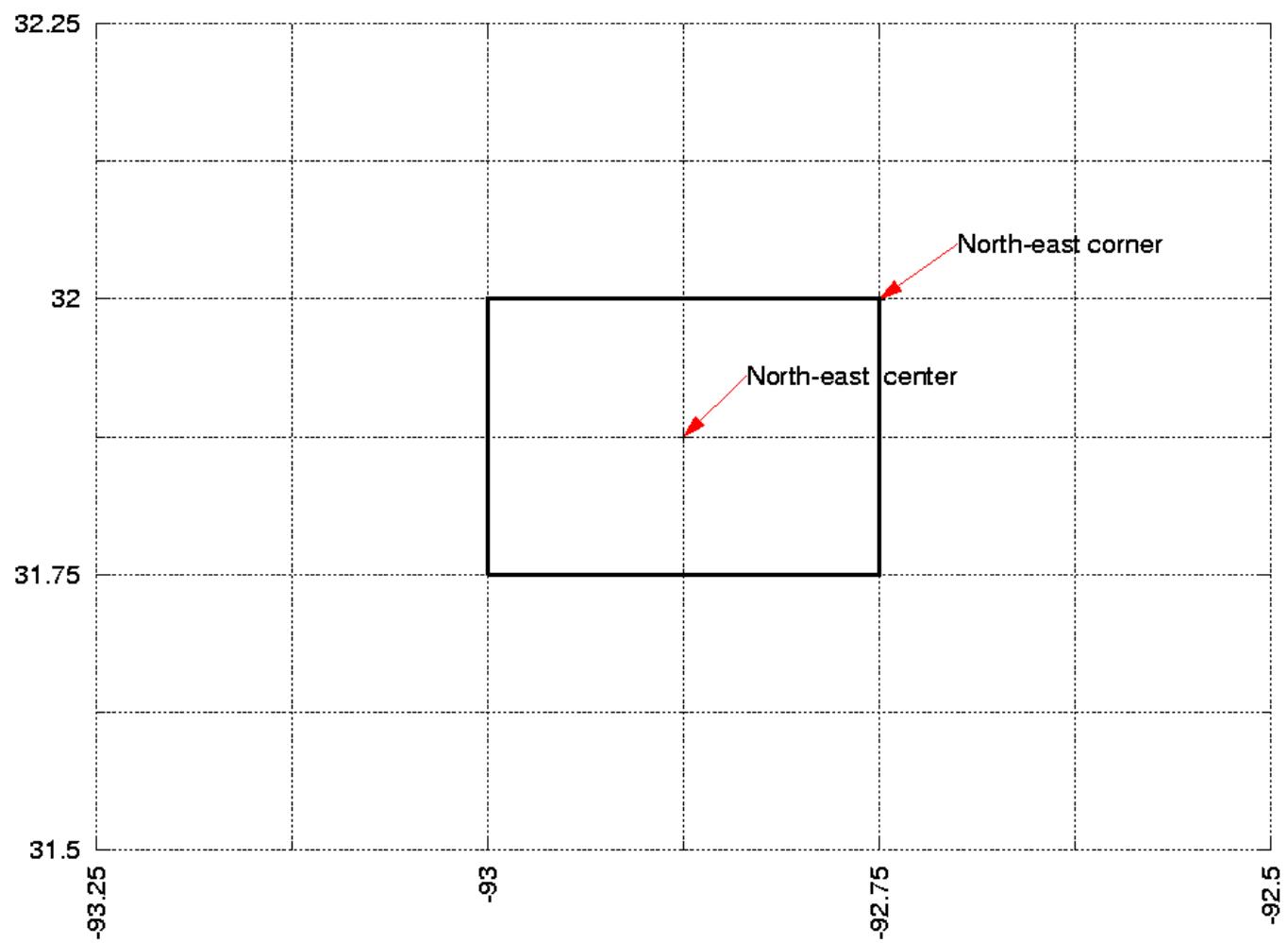


Figure 3: Illustration showing the north-east grid-cell corresponding to the example in Section C

D Polar Stereographic Domain Example

This section describes how to compute the values for the run domain and param domain sections on a polar stereographic projection.

STUB!

E Gaussian Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Gaussian projection.

First, we shall generate the values for the parameter data domain. LIS' Gaussian parameter data is defined from -180 to 180 degrees longitude and from -90 to 90 degrees latitude. Note that the first longitude point is at 0 .

The parameter domain must be specified as follows:

```
param domain first grid point lat:      -89.27665
param domain first grid point lon:      0.0
param domain last grid point lat:       89.27665
param domain last grid point lon:      -0.9375
param domain resolution dlon:          0.9375
param domain number of lat circles:    95
```

Next, we shall generate the values for the running domain.

If you wish to run over the whole domain defined by the parameter data domain then you simply set the values defined in the parameter domain section in the run domain section. This gives:

```
run domain first grid point lat:      -89.27665
run domain first grid point lon:      0.0
run domain last grid point lat:       89.27665
run domain last grid point lon:      -0.9375
run domain resolution dlon:          0.9375
run domain number of lat circles:    95
```

If you wish to run over a sub-domain, then you must choose longitude and latitude values that correspond to the T126 Gaussian projection. Tables of acceptable longitude and latitude values are found below.

Now say you wish to run only over the region given by $(-97.6, 27.9), (-92.9, 31.9)$. Since the running domain must fit on the T126 Gaussian grid, the running domain must be expanded to $(-98.4375, 27.87391), (-91.875, 32.59830)$. Thus the running domain specification is:

```
run domain first grid point lat:      27.87391
run domain first grid point lon:      -98.4375
run domain last grid point lat:       32.59830
run domain last grid point lon:      -91.875
run domain resolution dlon:          0.9375
run domain number of lat circles:    95
```

Table 1: Acceptable longitude values

0.000000	0.937500	1.875000	2.812500	3.750000
4.687500	5.625000	6.562500	7.500000	8.437500
9.375000	10.312500	11.250000	12.187500	13.125000
14.062500	15.000000	15.937500	16.875000	17.812500
18.750000	19.687500	20.625000	21.562500	22.500000
23.437500	24.375000	25.312500	26.250000	27.187500
28.125000	29.062500	30.000000	30.937500	31.875000
32.812500	33.750000	34.687500	35.625000	36.562500
37.500000	38.437500	39.375000	40.312500	41.250000
42.187500	43.125000	44.062500	45.000000	45.937500
46.875000	47.812500	48.750000	49.687500	50.625000
51.562500	52.500000	53.437500	54.375000	55.312500
56.250000	57.187500	58.125000	59.062500	60.000000
60.937500	61.875000	62.812500	63.750000	64.687500
65.625000	66.562500	67.500000	68.437500	69.375000
70.312500	71.250000	72.187500	73.125000	74.062500
75.000000	75.937500	76.875000	77.812500	78.750000
79.687500	80.625000	81.562500	82.500000	83.437500
84.375000	85.312500	86.250000	87.187500	88.125000
89.062500	90.000000	90.937500	91.875000	92.812500
93.750000	94.687500	95.625000	96.562500	97.500000
98.437500	99.375000	100.312500	101.250000	102.187500
103.125000	104.062500	105.000000	105.937500	106.875000
107.812500	108.750000	109.687500	110.625000	111.562500
112.500000	113.437500	114.375000	115.312500	116.250000
117.187500	118.125000	119.062500	120.000000	120.937500
121.875000	122.812500	123.750000	124.687500	125.625000
126.562500	127.500000	128.437500	129.375000	130.312500
131.250000	132.187500	133.125000	134.062500	135.000000
135.937500	136.875000	137.812500	138.750000	139.687500
140.625000	141.562500	142.500000	143.437500	144.375000
145.312500	146.250000	147.187500	148.125000	149.062500
150.000000	150.937500	151.875000	152.812500	153.750000
154.687500	155.625000	156.562500	157.500000	158.437500
159.375000	160.312500	161.250000	162.187500	163.125000
164.062500	165.000000	165.937500	166.875000	167.812500
168.750000	169.687500	170.625000	171.562500	172.500000
173.437500	174.375000	175.312500	176.250000	177.187500
178.125000	179.062500	180.000000	-179.062500	-178.125000

-177.187500	-176.250000	-175.312500	-174.375000	-173.437500
-172.500000	-171.562500	-170.625000	-169.687500	-168.750000
-167.812500	-166.875000	-165.937500	-165.000000	-164.062500
-163.125000	-162.187500	-161.250000	-160.312500	-159.375000
-158.437500	-157.500000	-156.562500	-155.625000	-154.687500
-153.750000	-152.812500	-151.875000	-150.937500	-150.000000
-149.062500	-148.125000	-147.187500	-146.250000	-145.312500
-144.375000	-143.437500	-142.500000	-141.562500	-140.625000
-139.687500	-138.750000	-137.812500	-136.875000	-135.937500
-135.000000	-134.062500	-133.125000	-132.187500	-131.250000
-130.312500	-129.375000	-128.437500	-127.500000	-126.562500
-125.625000	-124.687500	-123.750000	-122.812500	-121.875000
-120.937500	-120.000000	-119.062500	-118.125000	-117.187500
-116.250000	-115.312500	-114.375000	-113.437500	-112.500000
-111.562500	-110.625000	-109.687500	-108.750000	-107.812500
-106.875000	-105.937500	-105.000000	-104.062500	-103.125000
-102.187500	-101.250000	-100.312500	-99.375000	-98.437500
-97.500000	-96.562500	-95.625000	-94.687500	-93.750000
-92.812500	-91.875000	-90.937500	-90.000000	-89.062500
-88.125000	-87.187500	-86.250000	-85.312500	-84.375000
-83.437500	-82.500000	-81.562500	-80.625000	-79.687500
-78.750000	-77.812500	-76.875000	-75.937500	-75.000000
-74.062500	-73.125000	-72.187500	-71.250000	-70.312500
-69.375000	-68.437500	-67.500000	-66.562500	-65.625000
-64.687500	-63.750000	-62.812500	-61.875000	-60.937500
-60.000000	-59.062500	-58.125000	-57.187500	-56.250000
-55.312500	-54.375000	-53.437500	-52.500000	-51.562500
-50.625000	-49.687500	-48.750000	-47.812500	-46.875000
-45.937500	-45.000000	-44.062500	-43.125000	-42.187500
-41.250000	-40.312500	-39.375000	-38.437500	-37.500000
-36.562500	-35.625000	-34.687500	-33.750000	-32.812500
-31.875000	-30.937500	-30.000000	-29.062500	-28.125000
-27.187500	-26.250000	-25.312500	-24.375000	-23.437500
-22.500000	-21.562500	-20.625000	-19.687500	-18.750000
-17.812500	-16.875000	-15.937500	-15.000000	-14.062500
-13.125000	-12.187500	-11.250000	-10.312500	-9.375000
-8.437500	-7.500000	-6.562500	-5.625000	-4.687500
-3.750000	-2.812500	-1.875000	-0.937500	

Table 2: Acceptable latitude values

-89.27665	-88.33975	-87.39729	-86.45353	-85.50930
-84.56487	-83.62028	-82.67562	-81.73093	-80.78618
-79.84142	-78.89662	-77.95183	-77.00701	-76.06219
-75.11736	-74.17252	-73.22769	-72.28285	-71.33799
-70.39314	-69.44830	-68.50343	-67.55857	-66.61371
-65.66885	-64.72399	-63.77912	-62.83426	-61.88939
-60.94452	-59.99965	-59.05478	-58.10991	-57.16505
-56.22018	-55.27531	-54.33043	-53.38556	-52.44069
-51.49581	-50.55094	-49.60606	-48.66119	-47.71632
-46.77144	-45.82657	-44.88169	-43.93681	-42.99194
-42.04707	-41.10219	-40.15731	-39.21244	-38.26756
-37.32268	-36.37781	-35.43293	-34.48805	-33.54317
-32.59830	-31.65342	-30.70854	-29.76366	-28.81879
-27.87391	-26.92903	-25.98415	-25.03928	-24.09440
-23.14952	-22.20464	-21.25977	-20.31489	-19.37001
-18.42513	-17.48025	-16.53537	-15.59050	-14.64562
-13.70074	-12.75586	-11.81098	-10.86610	-9.921225
-8.976346	-8.031467	-7.086589	-6.141711	-5.196832
-4.251954	-3.307075	-2.362196	-1.417318	-0.4724393
0.4724393	1.417318	2.362196	3.307075	4.251954
5.196832	6.141711	7.086589	8.031467	8.976346
9.921225	10.86610	11.81098	12.75586	13.70074
14.64562	15.59050	16.53537	17.48025	18.42513
19.37001	20.31489	21.25977	22.20464	23.14952
24.09440	25.03928	25.98415	26.92903	27.87391
28.81879	29.76366	30.70854	31.65342	32.59830
33.54317	34.48805	35.43293	36.37781	37.32268
38.26756	39.21244	40.15731	41.10219	42.04707
42.99194	43.93681	44.88169	45.82657	46.77144
47.71632	48.66119	49.60606	50.55094	51.49581
52.44069	53.38556	54.33043	55.27531	56.22018
57.16505	58.10991	59.05478	59.99965	60.94452
61.88939	62.83426	63.77912	64.72399	65.66885
66.61371	67.55857	68.50343	69.44830	70.39314
71.33799	72.28285	73.22769	74.17252	75.11736
76.06219	77.00701	77.95183	78.89662	79.84142
80.78618	81.73093	82.67562	83.62028	84.56487
85.50930	86.45353	87.39729	88.33975	89.27665

F Lambert Conformal Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Lambert conformal projection.

STUB!

G Mercator Domain Example

This section describes how to compute the values for the run domain and param domain sections on a Mercator projection.

STUB!

H UTM Domain Example

This section describes how to compute the values for the run domain and param domain sections on a UTM projection.

References

- [1] S.V. Kumar, C.D. Peters-Lidard, J.A. Santanello, K. Harrison, Y. Liu, and M. Shaw. Land surface verification toolkit (lvt)- a generalized framework for land surface model evaluation. *Geosci. Model Dev.*, pages 869–886, 2012.
- [2] W. Sawyer and A. da Silva. Protex: A sample fortran 90 source code documentation system. Technical report, NASA GMAO, 1997. DAO Office Note 97-11.